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Abstract

Through an examination of the case of the iPhone X, this paper demonstrates that Chinese companies involved in production of the iPhone X have moved up the value chain. According to the bill of materials, those companies contributed 25% of the value added of the iPhone X. About 45% of the value added of the iPhone X originated from Japan, Korean and other economies. The iPhone trade remains a significant element of the statistics distortion of the Sino-US bilateral trade imbalance. In terms of gross value, the import of one iPhone X results in a $332.75 trade deficit for the US; measured in terms of value added, the deficit is a mere $104. Depreciation of the yuan has very limited power to counterbalance the tariffs imposed by the Trump administration because foreign value added embedded in Chinese exports is 33.9% on average. Simulation results show that to counterbalance a 25% tariff, the yuan would have to depreciate by 43.3% against the US dollar on average; and to fully compensate for a 25% tariff burden on the iPhone X, a 400% depreciation of the yuan would be necessary. Hedging the risk of the punitive US tariffs by depreciation of the yuan is mission impossible.

Key Words: China, US, Value Added, Trade and iPhone

JEL: F1

1. Introduction

In 2010, my research assistant Neal Detert and I published "How the iPhone widens the US trade deficit with China" (Xing and Detert, 2010). Based on the analysis of the Chinese export in the iPhone 3G to the US, the paper arrived at three conclusions. First, conventional trade statistics significantly exaggerated the US trade deficit with China, and value added, rather than gross value of exports, should be used to assess the bilateral trade balance between the US and China in the age of global value chains (GVC). Second, foreign value added embedded in the iPhone export substantially weakened the impact of exchange rates on the Sino-US bilateral trade balance, so that even a 50% yuan appreciation would have little impact on China's iPhone exports to the US, because foreign value added counted for 96.4% of the total production cost of the iPhone 3G. Finally, the paper concluded that profit maximization was Apple's motivation for having the iPhone assembled in China.

Since the 2007 release of the first generation iPhone, China has been the exclusive base for assembly of the iPhone. Assembly was the least value added task in the value chain of the iPhone; China received a mere $6.5 for assembling a ready-to-use iPhone 3G. After more than a decade, the iPhone has evolved into a luxury high-tech gadget, with not only the most advanced technologies but also a $1,000 price tag. Have the Chinese firms involved in the production of the iPhone moved up the ladder of the value chain? Do they perform more sophisticated tasks and capture more of the value added of the latest iPhone models? Does the iPhone remain a major source of the distortion of statistics on the bilateral trade imbalance between China and the US? To answer these questions, this paper takes the iPhone X as a case for replication of the analysis of the 2010 paper.

Since March 2018 the US has been waging a trade war with China. To achieve fair and reciprocal trade, the Trump administration has imposed a punitive 25% tariff on $250 billion worth of Chinese goods. It will levy a 15% tariff on an additional $300 billion in Chinese goods, effective December 2019 (Reuters, 2019). Since the start of the trade war, the Chinese yuan has been following a depreciation trend against the US dollar. The yuan–dollar exchange rate rose from 6.2 yuan/dollar to 7.10 yuan/dollar during the period of March 2018 to October 2019, a 14.5% nominal depreciation. Conventional wisdom fuels speculation that the Chinese government deliberately utilized the yuan's depreciation to counterbalance the punitive US tariffs. A research note by the Bank of America voiced expectation that a 10% depreciation of the yuan could completely cancel the impact of a 10% tariff (Tan, 2019). Alleging that the

Chinese government used depreciation as a trade war weapon, the Trump administration immediately designated China a “currency manipulator” after the yuan–dollar rate broke the 7.0 yuan/dollar psychological level (U.S. Department of the Treasury, 2019).

Can yuan depreciation really offset the negative impact of the punitive tariffs? The 2010 paper argues that, because of the foreign value added embedded in the iPhone 3G, appreciation of the yuan would have little impact on iPhone exports to the US. The same logics applies to the depreciation of the yuan. Because of foreign value added, the depreciation of the yuan would have a very limited effect in counterbalancing the burden of the 25% tariff imposed on Apple products assembled in China. Section 4 of this paper provides a theoretical explanation of the impossibility of hedging the risk of the punitive tariffs by means of yuan depreciation, and presents the results of a simulation of the yuan depreciation required under a variety of scenarios, where tariffs and foreign value added are two exogenous variables.

2. Moving Up the iPhone Value Chain

Grimes and Sun (2016) find that Chinese firms have played an increasingly important role in Apple’s value chains. In 2014, 14 of 198 companies in Apple’s supply chain were Chinese. A few of them supplied core components, e.g., displays and printed circuit boards. This suggests that Chinese firms have strengthened their presence in the value chains controlled by Apple. For an understanding of Chinese firms’ upward progress in the iPhone value chain, we examine the teardown data of the iPhone X to assess the involvement of Chinese firms in the production of the iPhone X, and estimate the value added captured by those firms. The teardown data identifies 10 domestic Chinese companies participating in the value chain of the iPhone X. Their tasks go beyond simple assembly to include roles in relatively sophisticated segments.

Sunwada, a leading Chinese battery maker, supplies the battery pack of the iPhone X. Sony batteries were used in the early iPhone models; Sunwada’s supplanting Sony as a battery pack supplier is a significant upgrading of Sunwada in the iPhone value chain. Kersen Technology provides the iPhone’s stainless frame, and Lens Technology manufactures the glass back cover (a first with the iPhone X). Together the stainless frame and glass back cover cost $53, about 13% of the total manufacturing cost of the iPhone X—more than 11 times the $4.5 assembly fee paid by Apple. In addition, Chinese companies Anjie Technology and Lushare Precision are involved in the manufacture of the iPhone X touch screen and 3D sensing module—critical technological components of the iPhone X. The former translates the user’s finger movements into data that can be interpreted as commands, while the latter is a key element of the facial recognition system introduced in the iPhone X. Chinese company Dongshan Precision joined the suppliers of Apple by acquiring American company M-Flex; it now supplies the printed circuit boards for the iPhone X for $15 per unit. Chinese companies Goertech, Shenzhen Sunway, Crystal-Optech and O-film provide functional parts: speakers, RF antennas, filters and camera modules, respectively. The involvement of those Chinese firms, though restricted to non-core technology segments of the iPhone X value chain, indicates that the Chinese mobile phone industry as a whole has moved to the upper rungs of the iPhone value chain ladder. Table 1 lists those Chinese firms and their corresponding tasks in the value chain of the iPhone X. Despite the extensive involvement of Chinese firms in the iPhone chain, our analysis reveals that all core components embedded in the printed circuit board assembly (PCBA), including processor, DRAM, NAND, display and camera, are supplied by non-Chinese companies: Apple, Qualcomm, Broadcom, Samsung, Toshiba, Sony and others.

Table 1 Tasks Performed by Chinese Firms for the iPhone 3G and iPhone X

3G iPhone (2009)	iPhone X (2018)
• Assembly (Foxconn) Total value added $6.5, 3.6% of the bill of materials.	• Assembly (Foxconn); • Functional parts for touchscreen module (Anjie Technology); • Filter for 3D sensing module (Crystal Optech); • Coil module for wireless charging (Lushare Precision); • Printed circuit board (M-Flex); • Speakers (Goertek); • RF antenna (Shenzhen Sunway); • Battery pack (Sunwada); • Glass cover (Lens Technology); • Stainless frame (Kersen Technology); • Camera module (O-Filem) Total value added: $104, 25.4% of the bill of materials.

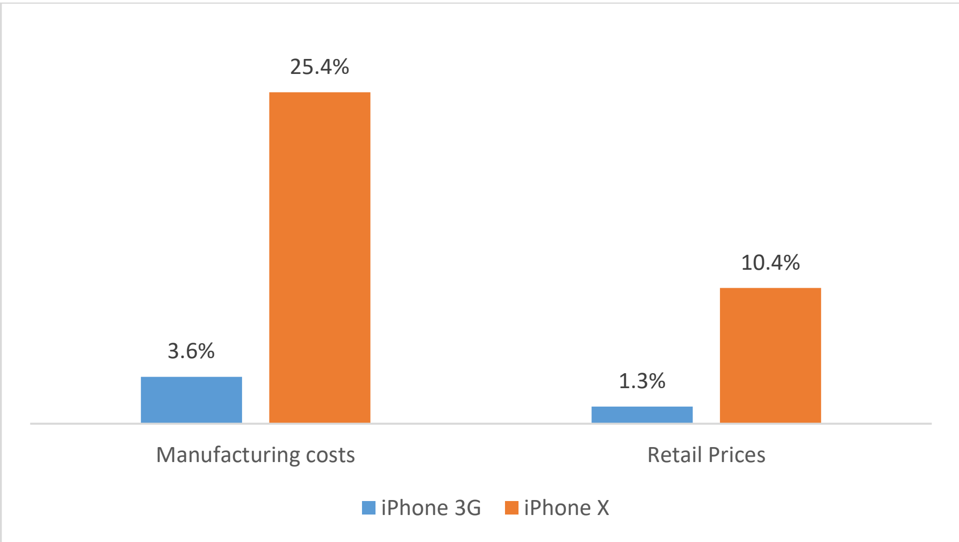
Source: Xing and Detert (2010) and the teardown data provided by the author's technical support team.

According to the teardown data, the bill of materials of the iPhone X is $409.25, of which the Chinese firms jointly contribute $104, or about 25.4% of the total manufacturing cost. That means that every iPhone X sold in the global market generates $104 income for the Chinese economy. Compared with the iPhone 3G, where Chinese value added was only $6.5, or about 3.6% of the total production cost, Chinese value added in the iPhone X is dramatically higher.

This implies significant upward movement by the Chinese firms along the iPhone value chain. The so-called “low value added trap” phenomenon is not present in the case of the Chinese firms participating the value chain of Apple.

The dominance of the iPhone in the global market and its worldwide popularity have little to do with China’s comparative advantage; rather they are the result of Apple’s constant technology innovation and marketing activities. The constantly rising demand for the iPhone in the world market always translates automatically into demand for the services and periphery components supplied by the Chinese companies. Apple’s global expansion always lifts China’s exports and its income. As the iPhone assembly base, China has benefited tremendously from the success of Apple. In 2018, Apple sold more than 217.72 million iPhones globally (Liu, 2019), contributing roughly $22.6 billion value added to the Chinese economy. This is clear evidence that participation in GVCs can greatly enhance the economic growth and industrialization of developing countries.

Figure 1: Chinese Value Added Embedded in the iPhone 3G and iPhone X



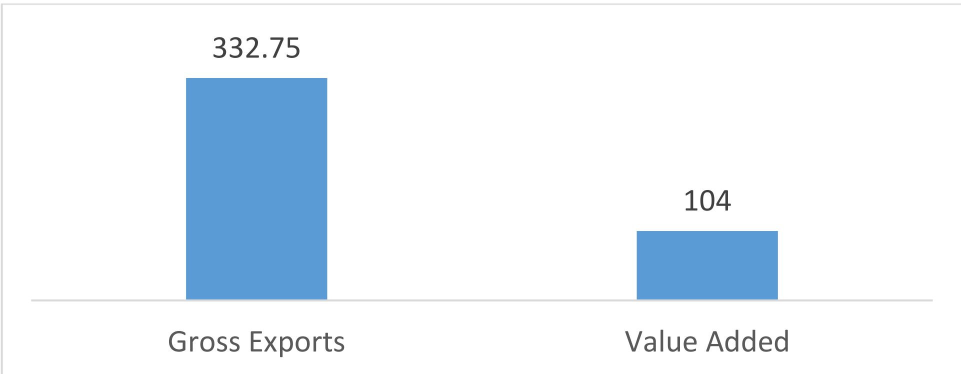
Source: Xing and Detert (2010) and the author’s calculation

A value chain consists of pre-production, production and post-production activities. For estimations of the share of domestic value added in a country’s exports and fair evaluations of its bilateral trade balances with trading partners, manufacturing cost of a product is the appropriate benchmark. On the other hand, for assessment of the value captured by Chinese firms in the entire iPhone X value chain, we should use retail price rather than production costs as a yardstick, since retail price proxies the total value added of the iPhone X. The retail price of the iPhone X torn down for this research is $1,000. Using the bill of materials, we calculate that $590.75, about 60% of the retail price, is attributed to the value added by Apple's retail service, brand and technology, and represents the gross profit margin of the iPhone X. Compared with the value added contributed by Apple, the $104 value added contributed by the Chinese firms is much smaller, just 10.4% of the total value added of the iPhone X. Figure 1 illustrates the Chinese value added of the iPhone X compared with that of the iPhone 3G. The figure clearly shows that the Chinese value added of the iPhone X is significantly higher than that of the iPhone 3G in both measures, implying a significant upgrading of the Chinese firms along the value chain of the iPhone.

3. The iPhone X: a Significant Source of the Bilateral Trade Imbalance

In 2018， US trade deficit with China in goods amounted $420 billion (U.S. Census Bureau, 2019). The huge and persistent trade deficit triggered the on-going Sino-US trade war. However, the bilateral trade imbalance between the two countries has been significant exaggerated by current trade statistics, which are inconsistent with GVC based modern trade. To date, trade statistics are still compiled based on gross value of exports, implicitly assuming that all gross value is generated by the exporting nation. According to that principle, whenever China ships one iPhone X to the US, the current system of trade statistics calculates it as a $409.25 export to the US, not including transportation cost. The teardown data reveals that the total value of the parts imported from the US for assembly of the iPhone X is $76.5. Hence, importing one iPhone X from China generates a $332.75 ($409.25–$76.5) trade deficit for the US. That is the conventional approach to calculation of bilateral trade balance.

Figure 2. US Trade Deficit with China for One Imported iPhone X ($)



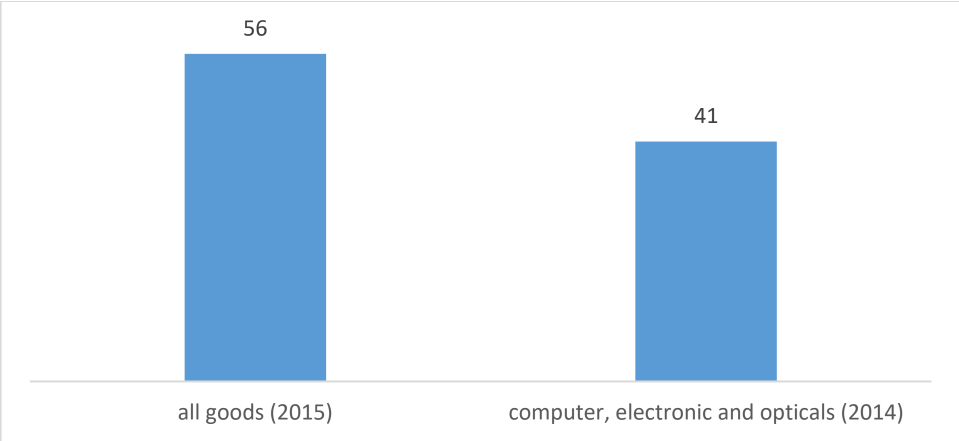
Source: the author's estimation based on the teardown data provided by the author's technical team.

On the other hand, the teardown data shows that Korea, Japan and other countries are also involved in the production of the iPhone X, supplying more than 45% of the parts and components. In other words, the $332.75 consists of not only value added originating in China but also that contributed by Korea, Japan and other non-US countries. Using the exporting-country-only figure to measure the trade balance surely exaggerates the US trade deficit with China. If measured in value added, the US deficit with China for the import of one iPhone X is only $104, less than one third of the figure based on gross value (figure 2). The difference between the two estimates is $228.75, implying that for every iPhone X imported, current trade statistics mistakenly add $228.75 to the US trade deficit with China. It is important to emphasize that it is the Apple that paid the cost of the parts sourced from designated Apple suppliers in US, Japan, Korean and other non-China countries. There is no $409.25 income transfer from the US to China when the US imports an iPhone X from China. The actual income transfer is the $104 paid for the assembly services and parts supplied by the Chinese firms.

Due to data constraints, we are unable to accurately assess the overall statistical distortion of the Sino-US trade imbalance associated with the iPhone trade in 2018. It is estimated that in 2017 American consumers bought 42.2 million units of iPhones (Finder, 2019), all of them imported from China. Using that figure as a reference, we infer that the iPhone trade inflated US trade deficit with China in 2018 by $9.65 billion, about 2.3% of the deficit. Therefore, the iPhone remains a significant source of the statistics distortion on the Sino-US bilateral trade imbalance.

The iPhone case convincingly demonstrates that conventional trade statistics significantly inflate China's trade imbalance with the US. It is shown above that, for evaluation of the bilateral trade balance, value added is a better tool than gross value trade. However, the iPhone X is an extreme case and cannot be taken as a general proxy for Chinese exports to the US. Many economists employ international input-output tables, which disclose country origins of intermediates, in their estimations of the US-China trade deficit in value added. Koopman, Wang, and Wei (2014) demonstrate theoretically how the value added of gross exports of individual countries can be traced with input-output tables. Johnson and Noguera (2012) adopt the same approach and conclude that the 2004 US-China trade imbalance would be 30-40% smaller if it were measured in value added. The OECD and WTO construct a database of trade in value added (TiVA) for estimating value added in the gross exports of more than 60 countries (OECD and WTO, 2013). The University of International Business and Economics in Beijing, China, also compiles a database, UIBE-GVC Indexes, to measure various parameters related to GVC participation and value added in trade. Here we employ UIBE-GVC Indexes data to calculate US overall trade deficit with China in value added and its deficit with China in the category of computers, electronics and opticals (the largest group of Chinese exports to the US). In 2015, US trade deficit with China, calculated as value added, was 56% of that calculated as gross value, and the trade deficit measured in value added for computers, electronics and opticals was 41% of that calculated as gross value (figure 3). Unambiguously, gross values of exports significantly exaggerate the US trade deficit with China. Conventional trade statistics are inconsistent with GVC based modern trade and substantially distort the actual bilateral trade balance between the US and China.

Figure 3. US Trade Deficit with China in Value Added (deficit in gross value =100)



Source: the author's calculation based on UIBE-GVC Indexes and the World Bank (2019)

4. Hedging Trump's Tariffs by Yuan Depreciation: Mission Impossible

The above analysis reveals that foreign value added accounts for 75% of the production cost of the iPhone X. The significantly large share of foreign value added embedded in the iPhone X exposes the vulnerability of the iPhones assembled in China to the punitive tariffs, which will be likely levied by the Trump administration if the trade war escalates further. All parts made in US, Japan, Korea and other countries for assembling iPhones in China will be subject to the tariffs too, when a ready-to-use iPhone X is shipped to the US. Even a substantial depreciation of the yuan cannot help Apple mitigate the burden of the tariffs. This explains why Apple has been so worried about the trade war.

When the Chinese yuan depreciates against the US dollar, only the $104 Chinese value added, representing the assembling fee and non-core components produced by the Chinese firms, will be affected. The rest of the iPhone X's production cost, $305.25, the sum of all parts and components shipped from foreign countries to China for assembling the iPhone X, will remain constant and not be affected whatsoever. However, if President Trump decides to levy a 25% tariff on the iPhone X imported from China, the tax base will be $409.25, i.e. the sum of both Chinese and foreign value added. In other words, the parts and components shipped to China from foreign countries, including the US, will be subject to the tariff.

A 25% depreciation of the yuan can surely offset the burden associated with the 25% tariff imposed on the Chinese value added. However, the $76.3 tax burden resulting from the 25% tariff levied on the foreign value added $305.25, remains. To offset the $76.3 tariff burden, the yuan would have to be depreciated much more than 25%. If not, Apple would either have to absorb it by lowering its profit margin, or pass it on to iPhone users. Given the $1,000 or higher price tags of iPhones, it is almost impossible to pass the burden to iPhone users. This explains Apple's vulnerability to the tariffs. If President Trump orders a 25% levy on iPhones, moving the assembly task of the iPhones destined for the US market out of China must be Apple's only choice. The analysis of the relationship between the tariff and the required level of yuan depreciation can be generalized for all Chinese exports to the US.

Let *TV* denote the total value added of Chinese exports to the US. In terms of the US dollar, *TV* can be written as

$$TV = \frac{DVA}{e} + FVA \qquad (1),$$

where *DVA* denotes the domestic value added measured in the yuan; *FVA* foreign value added in the US dollar; and *e* the exchange rate, i.e. the price of the dollar in the yuan. Let *t* be the tariff levied on Chinese goods by the US. If the yuan depreciates to the level e^* from e so that the tariff effect would be offset completely, e^* should meet the following condition

$$\frac{DVA}{e} + FVA = (\frac{DVA}{e*} + FVA)(1+t) \qquad (2).$$

Equation (2) implies that the price of Chinese exports to the US with the tariff is same as that without after the depreciation of the yuan.

Solving equation (2) yields

$$e* = \frac{DVA + DVA*t}{\frac{DVA}{e} - FVA*t} \quad (3)$$

The required depreciation as a percentage is

$$\propto = \frac{e^{*} - e}{e} \times 100\% = \left(\frac{1+t}{1-a*t} - 1\right) \times 100\% \quad (4)$$

where $a = FVA/(\frac{DVA}{e})$, the ratio of foreign value added to domestic value added.

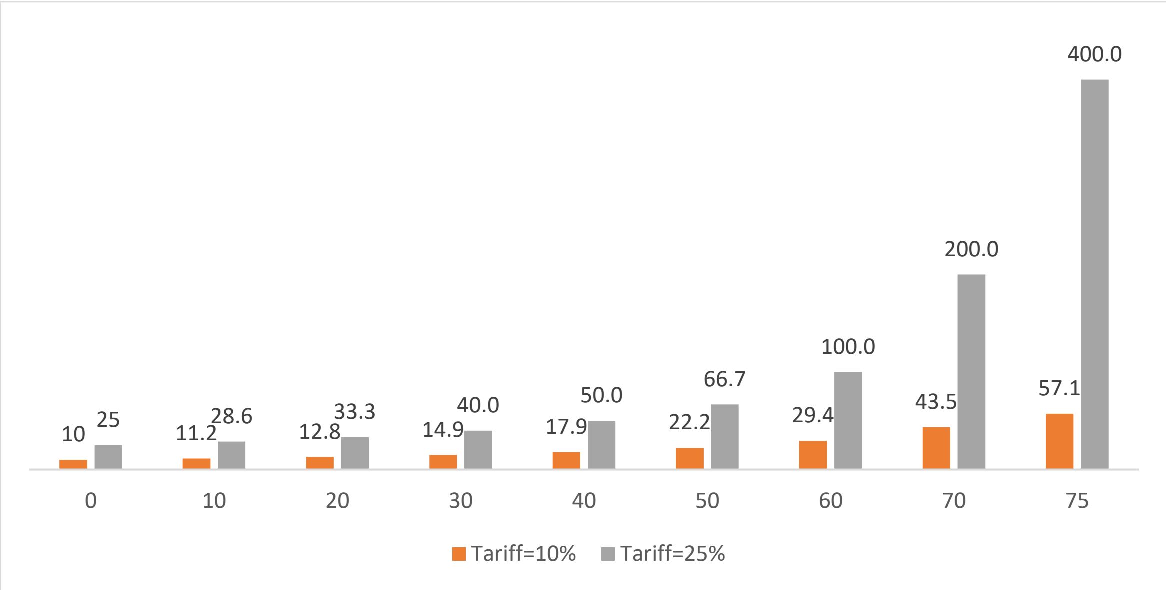
Using equation (4), we simulate different scenarios of yuan depreciation. In each case, the tariff and foreign value added are given. We consider two different tariffs, 10% and 25%, used by the Trump administration. Foreign value added is assumed to range from zero to 75%. The simulation results are presented in figure 4.

According to the simulation results, (1) the required yuan depreciation is higher than the corresponding tariff when foreign value added is greater than zero; (2) it rises rapidly as foreign value added increases; and (3) after foreign value added exceeds a certain threshold, the required yuan depreciation increases to an impossible level. Specifically, with a 10% tariff, 11.2% depreciation of the yuan can counterbalance the tariff if foreign value added is 10%; if the foreign value added rises to 50%, a 22.2% depreciation is needed; for exports with 75% foreign value added, the required depreciation is estimated at 57.1%, which is almost impossible according to the fundamentals of the Chinese economy. If the tariff levied on Chinese goods is raised to 25%, the required depreciation increases in all scenarios. The yuan would have to depreciate 28.6% in order to cancel the negative impact of the tariff if foreign value added is 10%; a 50% depreciation is necessary if foreign value added increases to 40%; and a 100% depreciation is required for Chinese exports with 60% of foreign value added.

The depreciation rates required to compensate for a 25% tariff are generally too high to be realized. In other words, it is impossible for China to use the depreciation of the yuan to hedge the risk of such a tariff. When foreign value added is zero, the required depreciation is just equal to the corresponding tariffs, implying that currency depreciation can be used as a policy tool to cope with punitive tariffs under conventional clothe-for-wine trade, where foreign value added is zero in all nations' exports.

According to UIBE-GVE Indexes, on average Chinese exports to the US contain 33.9% of foreign value added; in computers, mobile phones and opticals, average foreign value added is estimated to be 54%; our analysis for the iPhone X indicates foreign value added of 75%. Using equation (4), it is straightforward to derive that a 43.4% depreciation of the yuan is required to completely offset the negative impact of a 25% punitive tariff on all Chinese exports to the US on average, while an unthinkable 400% depreciation of the yuan is necessary to eliminate the negative impact of the same tariff levied on the iPhone X. To offset completely the negative impact of a 25% tariff on computers, mobile phones and opticals, a 76.9% depreciation of the yuan is necessary. Clearly, China cannot counterbalance a 25% punitive tariff by means of yuan depreciation without triggering economic turmoil.

Figure 4. Yuan Depreciation Required Offsetting Tariff Effects (%)



Source: the author's simulation results.

Since conventional approaches cannot eliminate tariff burdens, for MNEs using China to assemble products catering the US market, one feasible option is to shift part of their value chains out of China. Now 250 billion worth of Chinese goods is subject to 25% tariff. If the trade war continues to escalate, the rest of Chinese exports to the US, valued at $300 billion, will be subject to a 15% or even higher tariff in the foreseeable future. To cope with the tariff burden and prepare for related uncertainty, some of GVC lead firms have relocated their production facilities out of China or search for alternative sourcing partners and/or contract manufacturers in third countries, thus reshaping the China-centered GVCs geographically.

Chinese contract manufacturers are facing the risk of being replaced by suppliers from other countries. Many buyer-driven GVCs rely on China as a source of products. For example, Walmart imports some $50 billion in goods from China annually, about one tenth of total US imports from China. Walmart has 60,000 suppliers in China; H&M has about 800 there; and more than 90% of UNIQUE suppliers are located there. These lead firms purchase mainly labour-intensive products from Chinese suppliers. It is relatively easy for them to find alternative suppliers in other developing countries such as Vietnam, Bangladesh and Indonesia. Given the asymmetric power between lead firms and Chinese suppliers, the latter have little leverage to resist the re-organization of value chains. The further escalation of the trade war will not only undermine China's exports to the US, but more important, it will permanently undercut China's export capacity.

In a survey by the American Chamber of Commerce in China (2019), approximately 40.7% of respondents reported that they are considering relocating, or have relocated, their manufacturing facilities outside China. For those that are moving manufacturing out of China, Southeast Asia (24.7%) and Mexico (10.5%) are the top destinations. The slogan, "Designed in California by Apple, Assembled in China" is printed on the back of all Apple products, but the trade war has also prompted Apple to consider restructuring its China-centered value chains. Apple has asked its major suppliers to evaluate the cost implications of shifting 15-30% of their production capacity from China to Southeast Asia (Li and Cheng, 2019).

Such relocation is not limited to American companies. Many Japanese companies have sped up their China exit in anticipation of further escalation of the trade war. Nintendo, which has most of its Switch games assembled in China, has started moving production to Vietnam; Sharp is considering relocating production of its Dynabook laptops to Vietnam or Taiwan; and Ricoh has shifted production of US-bound multifunction printers from China to Thailand (Sese, 2019). Unambigously the trade war is reshaping China-centered value chains. The redeployment of the China-centered GVCs will permanently damage China's export capacity and China will no longer play a central role in the GVCs targeting the US market.

5. Concluding Remarks

Chinese companies involved in the value chain of the iPhone have climbed to the upper rungs of the ladder. Even companies that started as simple assemblers have not been trapped in low value added tasks. The analysis on the iPhone X presented here shows that, besides assembly, Chinese firms performed relatively sophisticated technological tasks and captured 25% of the value added according to the bill of materials, much higher than the 3.6% gained from assembly of the first generation of the iPhone. In terms of gross value, one iPhone X imported by the US results in a $332.75 trade deficit for the US. On the other hand, measured in value added, the deficit is only $104. Under current trade statistics practice, the iPhone remains a significant source of statistical distortion in calculations of the Sino-US bilateral trade imbalance.

To a certain extent, the depreciation of the yuan can alleviate the tariff burden of American companies importing “Made in China” products. However, the impact of yuan depreciation is very limited because of the foreign value added embedded in Chinese exports to the US, 33.9% on average. To completely offset the negative impact of a 25% tariff imposed on all Chinese exports to the US, the yuan should depreciate against the US dollar by 43.3% on average. Our simulation also suggests that, to fully compensate for a 25% tariff burden on the iPhone X, a 400% depreciation of the yuan is needed. Hence, hedging the risk of the punitive tariffs imposed by the Trump administration by depreciating the yuan is mission impossible.

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